Display Apparatus

BACKGROUND OF THE INVENTION

Field of the Invention

5   The present invention relates to an oblique projection type display apparatus and, more particularly, to a rear projection display apparatus designed to attain a reduction in depth of the apparatus by oblique projection.

10   Related Background Art

A conventional apparatus of this type is disclosed in WO 97/01787 or the like. Fig. 6 shows the arrangement of a projection optical system. The conventional technique shown in Fig. 6 is designed to

15   obliquely project an image of an image display panel onto a screen without any trapezoidal distortion by using three to four coaxial aspherical reflecting mirrors and one vertical plane mirror.

When embodiments in the above prior art are traced

20   and examined, it was found that a reception angle (corresponding to FNO) for a light beam emerging from an image display panel is a tradeoff for imaging performance (distortion characteristics, in particular), and it was difficult to obtain

25   satisfactory optical performance.

The mirror data in Table 1 and the ray trace diagram of Fig. 6 show the tracing/examination results

on an arrangement including three curved reflecting
mirrors and one plane mirror. In this
tracing/examination, the projection image maximum
distortion was 1.1% and projection image average MTF (1
LP/mm) was 30% at projection FNO = 6.0. Note that the
image display panel display size in this case was 34 mm
diagonal and 16 : 9 aspect ratio, and the enlarged
display size on the screen was 60" (1524 mm) diagonal.

Table 1

FNO	6.0			
Magnification	44.4			
Reflecting Surface NO	r (Radius of Curvature [mm])	d (Distance [mm])	K (Cone Constant)	
Panel Surface	infinity	215.65		
1	251.360	-281.88	0	
2	434.812	238.00	9.957637	
3	-146.786	-238.0	-6.882988	
Plane Mirror	infinity	295.00	0	
Screen	Infinity			
Reflecting Surface NO	A (Aspherical Constant)	B (Aspherical Constant)	C (Aspherical Constant)	D (Aspherical Constant)
1	0	0	0	0
2	0.171926E-6	-0.469882E-10	0.135238E-13	-0.158164E-17
3	0.519197E-8	-0.112461E-12	0.210605E-17	-0.172466E-22

Of the data in Table 1, the sign of the surface
distance d is reversed every time the propagating
direction of a light beam from the image display panel
is reversed when it is reflected by the curved

reflecting mirror. The signs "+" and "-" of the radius of curvature r respectively indicate concave and convex surfaces.

SUMMARY OF THE INVENTION

The present invention has been made to solve the above problems, and has as its object to provide a high-quality, high-precision, large-screen display apparatus which can obtain a sufficient light beam reception angle with respect to an image display unit, improve imaging performance, and obtain an ultra-low-profile structure.

In one aspect of the invention, there is provided a display apparatus which includes at least one image display means; and

a projection optical system for obliquely projecting image light from said at least one image display means onto a projection surface,

wherein said projection optical system includes a plurality of aspherical curved mirrors and projects the image light without distortion (not more than 1.2%).

In further aspect of the above display apparatus, the curved mirrors include at least six aspherical curved mirrors.

In further aspect of the above display apparatus, said projection optical system includes at least one plane mirror.

In further aspect of the above display apparatus, at least one of the plane mirrors is placed parallel to the projection surface.

In further aspect of the above display apparatus, said at least six aspherical curved mirrors and said at least one plane mirror are sequentially arranged from the image display means side.

In further aspect of the above display apparatus, an aperture stop is provided between said image display means and said projection optical system.

In further aspect of the above display apparatus, an aperture stop is provided between said image display means and said projection optical system.

In further aspect of the above display apparatus, an aperture stop is provided between a second curved mirror and a third curved mirror from the image display means side.

In further aspect of the above display apparatus, an aperture stop is provided between said image display means and the curved mirror.

In further aspect of the above display apparatus, an aperture stop is provided between a second curved mirror and a third curved mirror from the image display means side.

In further aspect of the above display apparatus, said projection optical system includes:

at least two plane mirrors arranged parallel to

the projection surface; and

an aperture stop.

In further aspect of the above display apparatus,

the projection surface receives light from said

5   image display means and

the projection surface is constructed such that at

least two eccentric Fresnel plates which have

substantially the same structure are stacked on each

other.

10   In further aspect of the above display apparatus,

light from said image display means is projected on the

projection surface from a rear surface thereof.

In another aspect of the invention, there is

provided an image processing apparatus which includes

15   said display apparatus set out in the foregoing; and

an image information input device for supplying

image information to said display apparatus.

In further aspect of the above image processing

apparatus, said image information input device

20   comprises an arithmetic unit (computer).

In another aspect of the invention, there is

provided a display apparatus which includes at least

one image display means;

a projection surface; and

25   a projection optical system for obliquely

projecting image light from said at least one image

display means onto said projection surface,

wherein said projection optical system includes at least six aspherical curved mirrors and a plurality of plane mirrors which are sequentially arranged from the image display means side.

5   In further aspect of the above display apparatus, an aperture stop is provided between said curved mirror and said image display means.

In further aspect of the above display apparatus, an aperture stop is provided between second and third

10   mirrors of the curved mirrors from said image display means.

In another aspect of the invention, there is provided a projection optical system for obliquely projecting light from image display means, comprising a

15   plurality of aspherical curved mirrors, wherein an image is projected without distortion (not more than 1.2%).

BRIEF DESCRIPTION OF THE DRAWINGS

20   Fig. 1 is a sectional view showing the arrangement of a low-profile rear projection display apparatus according to the first embodiment of the present invention;

Fig. 2 is an enlarged sectional view showing the

25   arrangement of the projection system of the low-profile rear projection display apparatus according to the first embodiment of the present invention;

Fig. 3 is a sectional view showing the arrangement of an oblique incident screen according to the first embodiment of the present invention;

Fig. 4 is a sectional view showing the arrangement of a thin rear projection display apparatus according to the second embodiment of the present invention;

Fig. 5 is an enlarged sectional view showing the arrangement of the projection system of the thin rear projection display apparatus according to the second embodiment of the present invention; and

Fig. 6 is a view showing an overall conventional low-profile rear projection optical system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to embodiments of the present invention, a projection system using six or more free-form mirrors is formed by applying the above arrangement so as to satisfy both the requirements for a sufficient light beam reception angle with respect to an image display panel and an improvement in imaging performance. This makes it possible to perform rear projection display on an ultra-thin, high-quality, high-precision, large screen.

The embodiments of the present invention will be described below.

First Embodiment

Fig. 1 is a sectional view showing the arrangement

of a thin rear projection display apparatus according

to the first embodiment of the present invention.

Referring to Fig. 1, this apparatus includes an oblique

incident screen 1, AL-deposited plane mirrors 2 and 3,

5   AL-deposited free-form mirrors 4, 5, 6, 7, 8, and 9

which are rotationally asymmetric aspherical curved

mirrors, a liquid crystal display device 10, and a

casing 25. Note that the rectangular portion

surrounded by the dashed line in Fig. 1 is a portion

10   that is additionally written to facilitate the

understanding of an oblique incident projection system

basic to the present invention, and a rendering of

projection without the plane mirrors 2 and 3.

Although Fig. 1 does not show parts other than

15   those described above, the liquid crystal display

device 10 is illuminated from the rear by an

illumination system (not shown), and image light

emerging from the front surface of the liquid crystal

display device 10 travels toward the free-form mirror

20   9. As will be described in detail later, a light beam

travels while being sequentially reflected by the

free-form mirrors 4, 5, 6, 7, 8, and 9, and is finally

reflected by the mirror 4 to emerge toward the plane

mirror 3, as shown in the ray diagram of Fig. 1. In

25   this case, this apparatus has an imaging effect based

on combining of light beam reflection angle modulation

effects of the respective surfaces, i.e., the overall

effect of the six surfaces.

This imaging effect serves to enlarge/project the rectangular image surface of the liquid crystal panel 10 on the screen 1, which is placed obliquely with

5   respect to the optical axis (optical axis incident angle of 42°). As shown in Fig. 1, therefore, a light beam emerging from the free-from mirror 4 is reflected first by the plane mirror 3 located below the screen 1, and the reflected light beam is further reflected by

10   the plane mirror 2, which is located on the upper rear side of the apparatus, toward the upper front side. Thereafter, the screen 1 is irradiated with this light beam from below obliquely upward. That is, the image light is obliquely projected on the screen 1 in the

15   end.

Note that the plane mirrors 2 and 3 are vertically arranged to be parallel with each other, together with the screen 1. With this layout, when a rear projection display apparatus is to be formed, its depth can be

20   greatly decreased. According to this embodiment, a 9 : 16 aspect ratio (landscape), 60" diagonal display screen with a depth of 30 cm can be expected.

The overall arrangement and mechanism have been described so far. The projection system comprised of

25   the free-form mirrors 4, 5, 6, 7, 8, and 9 and an aperture 11 will be described next.

Fig. 2 is an enlarged sectional view of the

projection system. Table 2 shows the optical data (the surface separations of the respective surfaces, the tilt angles of the respective surfaces, the surface definitions of the respective surfaces, and the like)

5   of the projection system. Note that the liquid crystal panel display size in this embodiment is 27 mm diagonal & 16 : 9 aspect ratio, and the enlarged display size on the screen is 60" (1524 mm) diagonal & 16 : 9 aspect ratio. With regard to coordinate systems in this case,

10   the local coordinates on the respective surfaces (free-from reflecting surfaces in this case) are used to define the respective surfaces.

The center of the liquid crystal panel 10 is set as a first origin, and a normal passing through the

15   origin is set as a first optical axis/z-axis (local z-axis) for defining a liquid crystal surface. The direction in which light emerges from the liquid crystal surface is defined as a positive z-axis direction. In this case, the y-axis is an axis

20   coinciding with the upward direction as a positive direction on the drawing surface which is perpendicular to the z-axis, and the x-axis is an axis coinciding with the forward direction as a positive direction on the drawing surface which is perpendicular to the z-

25   and y-axes.

A point apart from a coordinate value on each reflecting surface by a surface distance d (mm) along the z-axis (optical axis) is set as a next local

origin.   If a given surface has a tilt angle, the
x-axis is set as a rotation axis, and the direction in
which the positive y-axis direction approaches the
positive z-axis direction (optical axis direction) is
5   set as a positive direction.   The x-, y-, and z-axes
after the tilt are set as local coordinates for
defining the reflecting surface.   The free-form surface
shapes of these reflecting surfaces are defined by an
xy polynomial as follows:

10
$$z = C_4x^2+C_6y^2+C_8x^2y+C_{10}y^3+C_{11}x^4+C_{13}x^2y^2+C_{15}y^4+C_{17}x^4y+C_{19}x^2y^3+$$
$$C_{21}y^5+C_{22}x^6+C_{24}x^4y^2+C_{26}x^2y^4+C_{28}y^6$$

Table 2 given below shows the respective C_n coefficient
values and the like as the respective reflecting
surface data.

15   Note that coordinate systems after reflection at
the reflecting surfaces conform to the above coordinate
definitions except that the z-axis polarity of the next
local coordinate system is reversed with respect to the
traveling direction of light.   In this embodiment,
20   therefore, the local coordinate system is defined such
that the z-axis (optical axis) polarity is reversed for
every reflection, and the signs of the surface distance
d and tilt angle are reversed for each reflection.

        In the projection system formed by a total of six
25   free-from mirror surfaces, the free-form mirror formed
by molding and AL deposition is held by a die cast
frame (not shown) to be arranged in accordance with the
optical data shown in Table 2.

Table 2

FNO	3.5 (based on relationship with aperture size)				
Magnification	56.4				
Surface	d[mm] (Surface Distance)		Tilt Angle [°] (rotation axis coincides with positive direction that is tilt direction in which x-axis/positive y direction rotates in positive z-axis direction)		
Liquid Crystal Surface	120.355	0			
Ninth Surface	-62.000	24.10			
Eighth Surface	20.000	-45.00			
Aperture	66.054	0			
Seventh Surface	-65.000	36.37			
Sixth Surface	60.952	-32.48			
Fifth Surface	-112.928	30.00			
Fourth Surface	95.1499	-20.49			
Plane Mirror 3	-295.000	42.00			
Plane Mirror 2	295.000	-42.00			
Screen		42.00			
Reflecting Surface	C_4	C_6	C_8	C_{10}	
Ninth Surface	-4.5884E-3	-3.4275E-3	2.5854E-6	4.3012E-7	
Eighth Surface	-5.4838E-3	-1.7940E-3	7.3906E-5	5.1839E-6	
Seventh Surface	4.1171E-4	-4.4187E-4	5.6620E-5	-1.6014E-5	
Sixth Surface	2.2449E-3	1.2939E-3	4.6241E-5	-1.2609E-5	
Fifth Surface	1.1310E-3	2.5863E-3	3.7000E-5	5.9829E-6	
Fourth Surface	5.3472E-3	3.7596E-3	-2.3969E-5	-1.6790E-5	
Reflecting Surface	C_{11}	C_{13}	C_{15}	C_{17}	C_{19}
Ninth Surface	-1.1349E-7	-1.7316E-7	-7.1215E-8	2.4169E-10	6.9478E-11
Eighth Surface	-4.9216E-7	-8.3895E-7	-2.0548E-7	1.6790E-8	1.4899E-8
Seventh Surface	5.3979E-7	-5.5956E-8	1.1600E-7	1.3042E-8	5.6446E-9
Sixth Surface	1.2510E-7	-4.2937E-8	1.1542E-7	9.0994E-10	6.9117E-10
Fifth Surface	-4.4928E-8	-3.4118E-7	4.7489E-7	-3.8844E-10	-5.7955E-9
Fourth Surface	-5.0709E-8	2.0786E-7	1.9881E-7	5.2909E-10	-9.6599E-10
Reflecting Surface	C_{21}	C_{22}	C_{24}	C_{26}	C_{28}
Ninth Surface	-1.7555E-10	-6.7660E-12	-1.4753E-11	-1.0332E-11	-4.3099E-12
Eighth Surface	1.2259E-9	8.0779E-11	-3.3503E-10	-1.0214E-10	-1.5825E-11
Seventh Surface	-7.856E-10	6.2334E-11	2.3367E-10	-2.3841E-11	5.1577E-12
Sixth Surface	3.4598E-10	-3.3328E-12	5.0336E-12	-9.1553E-12	-5.3798E-13
Fifth Surface	3.5909E-9	-5.4674E-12	-5.8379E-11	-1.4892E-10	1.4863E-10
Fourth Surface	-1.6141E-9	1.0377E-11	-4.8012E-12	4.5601E-12	8.8339E-12

According to the optical specifications achieved by this projection system, although the incident angle on the screen is as severe as 42°, the distortion is 0.5% or less, the average MTF is 80% (1 Lp/mm), the FNO

5   is 3.5, and the brightness unevenness is 20% or less. That is, a sufficient light beam reception angle (FNO: 3.5) and imaging performance can be obtained; the achieved specifications can be applied to high-resolution, high-quality, image projection of a

10 so-called high-vision level.

As the screen 1, a screen for oblique incidence is used in this embodiment. Fig. 3 shows a sectional arrangement of this screen. The screen is made up of three members, i.e., an eccentric Fresnel plate 12,

15 eccentric Fresnel plate 13, and lenticular member 14, which are sequentially stacked on each other from the incident side. In this case, as these eccentric Fresnel plates 12 and 13, two mirrors having the same specifications are used (because such a severe

20 requirement for oblique incidence cannot be satisfied by using only one eccentric Fresnel plate in terms of prism processing). As indicated by the thin arrow lines in Fig. 3, owing to the beam condensing effect of the two eccentric Fresnel plates, projection light

25 incident from the rear side emerges from the entire surface in the forward direction (in other words, the power and eccentricity amount of each eccentric Fresnel

plate are so set to obtain such refracting effect). In this case, the projection light diverges in the horizontal direction (the vertical direction in Fig. 3) by the lenticular member 14, and a projection image

5   with uniform brightness is observed from the viewer side on the front side throughout a wide field of view.

This eccentric Fresnel plate can be formed by cutting a plate from a general concentric Fresnel plate at a position offset from its center by a predetermined

10   distance.

As described above, according to this embodiment, although a sufficient light beam reception angle, i.e., FNO: 3.5, and the above excellent imaging performance can be obtained, if the number of free-form surfaces is

15   reduced to 4 or 5, an inconvenience occurs in terms of an optical parameter associated with MTF, distortion, or the like. According to the study conducted by the present applicants, no good effect could be obtained. This may be because if desired optical performance is

20   to be obtained even under a severe condition, i.e., oblique incidence, a corresponding number of variable parameters are required.

The arrangement described above is merely an embodiment, and hence can be variably arranged. In

25   this embodiment, six free-form mirrors are used to form a projection system. However, seven or more mirrors may be used without posing any problem. In addition,

the liquid crystal panel is used as a display device.
However, the present invention is not limited to this,
and a thin rear projection display apparatus can be
formed by using a reflection type device such as a DMD,

5   an organic EL display device, or the like.
Furthermore, as for the screen arrangement, the
lenticular member may be replaced with a diffusion
plate, and the eccentric Fresnel plate may be replaced
with a linear Fresnel plate, hologram plate, hologram

10   sheet, or the like.

Second Embodiment

       Fig. 4 is a sectional view showing the arrangement
of a thin rear projection display apparatus according
to the second embodiment of the present invention.

15   Referring to Fig. 4, this apparatus includes an oblique
incident screen 23, AL-deposited plane mirror 24,
Al-deposited free-from mirrors 15, 16, 17, 18, 19, and
20, DMD display device 21, and casing 26.   Note that as
DMD display devices, for example, the devices disclosed

20   in Japanese Patent Nos. 2664300, 2978224, and 2978285
are widely known.

       Although Fig. 4 does not show parts other than
those described above, the DMD display device 21 is
illuminated from an upper side by an illumination

25   system (not shown), and image light reflected from the
DMD display device 21 travels toward the free-form
mirror 20.   As in the above embodiment, a light beam

travels while being sequentially reflected by the
free-form mirrors 15, 16, 17, 18, 19, and 20 is finally
reflected by the mirror 20 to emerge toward the plane
mirror 24, as shown in the ray diagram of Fig. 4. In

5   this case, this apparatus has an imaging effect based
on the synthesis of light beam reflection angle
modulation effects of the respective surfaces, i.e.,
the overall effect of the six surfaces.

        This imaging effect serves to enlarge/project the
10   rectangular image surface of the DMD panel 21 on the
screen 23, which is placed obliquely with respect to
the optical axis (optical axis incident angle of
40.3°). As shown in Fig. 4, therefore, a light beam
emerging from the free-from mirror 20 is reflected by
15   the plane mirror 24 located behind the screen, i.e., on
the rear side of the apparatus. Thereafter, the screen
23 is irradiated with this light beam from below
obliquely upward. That is, the image light is
obliquely projected on the screen 23 from a lower side.

20   Note that the plane mirror 24 is vertically placed
to be parallel with the screen 23. With this layout,
as in the above embodiment, when a rear projection
display apparatus is to be formed, its depth can be
greatly decreased. According to this embodiment, a 5 :
25   3 aspect ratio (landscape), 60" diagonal display screen
with a depth of 30 cm can be expected. In addition, in
this embodiment, only one plane mirror is used, and the

free-form mirrors 15, 16, 17, 18, 19, and 20 extend

parallel to the rear projection apparatus. This layout

allows a reduction in the total height of the apparatus

as compared with the preceding embodiment. As for the

5   above screen size, a total height of 110 cm or less can

be expected.

The overall arrangement and mechanism have been

described so far. The projection system comprised of

the free-form mirrors 15, 16, 17, 18, 19, and 20 and an

10   aperture 22 will be described next. Fig. 5 is an

enlarged sectional view of the projection system.

Table 3 shows the optical data (the surface separations

of the respective surfaces, the tilt angles of the

respective surfaces, the surface definitions of the

15   respective surfaces, and the like) of the projection

system. Note that the DMD panel display size in this

embodiment is 21 mm diagonal & 5 : 3 aspect ratio, and

the enlarged display size on the screen is 60" (1524

mm) diagonal & 5 : 3 aspect ratio. With regard to

20   coordinate systems in this case, the local coordinates

on the respective surfaces (free-from reflecting

surfaces in this case) are used to define the

respective surfaces.

The center of the DMD panel 21 is set as a first

25   origin, and a straight line connecting the origin and

the center of the aperture 22 is set as a first optical

axis/z-axis (local z-axis). The direction in which

light emerges from the liquid crystal surface is

defined as a positive z-axis direction. In this case,

the y-axis is an axis coinciding with the leftward

direction as a positive direction on the drawing

5   surface which is perpendicular to the z-axis, and the

x-axis is an axis coinciding with the forward direction

as a positive direction on the drawing surface which is

perpendicular to the z- and y-axes.

As in the preceding embodiment, a point separated

10   from a coordinate value on each reflecting surface by a

surface distance d (mm) along the z-axis (optical axis)

is set as a next local origin. If a given surface has

a tilt angle, the x-axis is set as a rotation axis, and

the direction in which the positive y-axis direction

15   approaches the positive z-axis direction (optical axis

direction) is set as a positive direction. The x-, y-,

and z-axes after the tilt are set as local coordinates

for defining the reflecting surface. In this

embodiment, the DMD panel itself is tilted at +38.017°.

20   The free-form surface shapes of these reflecting

surfaces are defined by an xy polynomial as follows:

$$z = C_4 x^2 + C_6 y^2 + C_8 x^2 y + C_{10} y^3 + C_{11} x^4 + C_{13} x^2 y^2 + C_{15} y^4 + C_{17} x^4 y + C_{19} x^2 y^3 +$$
$$C_{21} y^5 + C_{22} x^6 + C_{24} x^4 y^2 + C_{26} x^2 y^4 + C_{28} y^6$$

Table 3 given below shows the respective C_n coefficient

25   values and the like as the respective reflecting

surface data.

Note that coordinate systems after reflection at

the reflecting surfaces conform to the above coordinate definitions except that the z-axis polarity of the next local coordinate system is reversed with respect to the traveling direction of light. In this embodiment,

5   therefore, the local coordinate system is defined such that the z-axis (optical axis) polarity is reversed for every reflection, and the signs of the surface distance d and tilt angle are reversed for each reflection.

As in the preceding embodiment, in the projection

10   system formed by a total of six free-from mirror surfaces, the free-form mirror formed by molding and AL deposition is held by a die cast frame (not shown) to be arranged in accordance with the optical data shown in Table 3.

Table 3

FNO	4.6 (based on aperture size)				
Magnification	72.5				
Surface	d[mm] (Surface Distance)		Tilt Angle [°] (rotation axis coincides with positive direction that is tilt direction in which x-axis/positive y direction rotates in positive z-axis direction)		
DMD Surface Aperture 20th Surface 19th Surface 18th Surface 17th Surface 16th Surface 15th Surface Plane Mirror Screen	83.000 15.836 -43.930 44.627 -73.116 60.558 -100.042 354.000 -354.000	38.017 0.000 38.603 -43.151 56.766 -31.851 35.889 -21.999 40.30 -40.30			
Reflecting Surface	C_4	C_6	C_8	C_{10}	
20th Surface 19th Surface 18th Surface 17th Surface 16th Surface 15th Surface	-5.5542E-3 -1.7045E-3 5.4890E-3 4.5864E-3 9.6278E-3 7.8106E-3	-3.8935E-3 -1.3621E-3 2.1130E-3 1.8464E-3 1.5852E-3 4.3619E-3	-1.8045E-5 -1.1014E-4 -5.4810E-5 -8.1612E-6 1.9096E-5 3.3695E-5	-6.4231E-6 -3.6759E-5 3.9701E-5 2.6422E-6 -2.5710E-5 1.7541E-5	
Reflecting Surface	C_{11}	C_{13}	C_{15}	C_{17}	C_{19}
20th Surface 19th Surface 18th Surface 17th Surface 16th Surface 15th Surface	-2.1321E-7 -9.5505E-7 -3.3133E-7 -7.9480E-8 -6.4138E-6 1.6671E-7	-4.7665E-7 -2.9033E-6 7.0577E-8 4.0016E-7 3.7365E-6 1.7313E-8	-1.7739E-7 -1.3288E-6 3.0403E-7 1.6277E-7 6.6103E-7 1.3574E-7	-3.2345E-9 -5.8551E-8 -9.4654E-9 -2.0123E-9 1.3636E-9 1.1791E-9	-1.5098E-9 -1.0072E-7 -3.6720E-8 1.4100E-9 5.1520E-8 -4.6506E-9
Reflecting Surface	C_{21}	C_{22}	C_{24}	C_{26}	C_{28}
20th Surface 19th Surface 18th Surface 17th Surface 16th Surface 15th Surface	-5.4541E-10 -3.3646E-8 -3.7392E-9 -5.0361E-9 3.3848E-11 1.7954E-9	2.6900E-12 2.0071E-11 8.8691E-10 -2.0956E-11 2.5347E-9 8.8106E-12	-6.3213E-11 -2.2254E-9 8.4074E-10 4.4791E-11 -1.6434E-9 1.7533E-11	9.0113E-12 -2.1570E-9 -2.4130E-10 -1.4289E-10 -1.8916E-9 -2.2737E-11	2.2693E-12 -4.8443E-10 1.8190E-11 -4.3554E-11 -3.7693E-10 2.1279E-11

According to the optical specifications achieved by this projection system, although the incident angle on the screen is as severe as 40.3°, the distortion is 1.2% or less, the average MTF is 40% (1 Lp/mm), the FNO

5   is 4.6, and the brightness unevenness is 20% or less. That is, a sufficient light beam reception angle (FNO: 4.6) and imaging performance for a DMD panel can be obtained. As in the preceding embodiment, the achieved specifications can be applied to high-quality image

10   projection of a DTV or the like. Strictly speaking, in this embodiment, although the optical performance slightly deteriorates as compared with the preceding embodiment, the total height of the apparatus can be decreased more.

15   The screen 23 in this embodiment is identical to the screen 1 in the preceding embodiment.

In the above embodiments, one or two plan mirrors are used. However, a further reduction in the depth of a display apparatus may be attained by folding the

20   optical path using three or more plane mirrors.

In addition, an image processing apparatus may be formed by combining the display apparatus of this embodiment and an image information input device for supplying image information. This image processing

25   apparatus may be a video deck or the like or an arithmetic unit such as a computer.

As has been described above, this embodiment can

satisfy both the requirements for a sufficient light

beam reception angle with respect to an image display

panel and an improvement in imaging performance. This

makes it possible to realize a high-quality,

5   ultra-thin, large-screen display apparatus.